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ABSTRACT

Many educational questions of research interest focus on individual differences in attitudes and behaviors related to academic achievement, changes in such attitudes and behaviors over time, and the types of academic environments that facilitate or prevent development of achievement attitudes and behaviors at school. This paper, the first in a 3-part series on modeling academic development, emphasizes the importance of studying intraindividual development and interindividual differences in intraindividual development. The paper presents a multilevel ecological model as a heuristic for exploring these types of educational questions and describes the use of various data analysis models for examining intraindividual academic growth patterns and interindividual differences in those patterns. It differentiates an incremental view and a process view of quantitative change and examines methods for analyzing longitudinal data related to student achievement. The paper concludes by noting that problems with measuring and analyzing change in academic achievement are derived from an inaccurate conceptualization of change. It is argued that research on academic development is challenging because an examination of student growth involves nested structures of repeated observations within individuals who in turn are nested within school settings. Hierarchical linear models are presented as an approach that can consider each student as a group, allowing repeated measures within each subject. Further, the paper shows that a growth curve approach in hierarchical linear models makes it possible to study intraindividual change and to examine which characteristics may be associated with interindividual differences in intraindividual change. (Contains 41 references.) (KB)

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Modeling children's academic development at school - Part I:
Contrasting quantitative approaches to the analysis of change

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Abstract

This paper emphasizes the importance of studying intra-individual development and inter-individual differences in intra-individual development. Educational questions, e.g. Why do some students acquire attitudes and behaviors that are conducive to high academic achievement?; Why do students develop these attitudes and behaviors in one direction or another (i.e., some becoming engaged in the academic environment of school while others become distant as evidenced by increased truancy)?; What classroom and/or school environments facilitate or prevent the development of achievement attitudes and behaviors at school?, can be examined for intra-individual academic growth patterns and inter-individual differences in those patterns using multilevel models.

Modeling children's academic development at school - Part I:

Contrasting quantitative approaches to the analysis of change

Introduction

Changes in individual's life trajectories across multiple contexts are of primary interest to those who study intra-individual quantitative change. Intra-individual academic development and the study of inter-individual differences in academic growth should also be of fundamental importance to applied educational researchers who seek to understand the learning processes of students and their academic products. Various quantitative approaches for studying intra-individual academic development and inter-individual differences in academic growth exist today. These approaches can answer educational questions like: (1) Why do some students acquire attitudes and behaviors that are conducive to high academic achievement?, (2) Why do students develop these attitudes and behaviors in one direction or another (e.g., some becoming more engaged in the academic environment of school while others become more distant as evidenced by increased truancy), or why do others show no changes in attitudes or behaviors at all?, and (3) What classroom and/or school environments facilitate or prevent the development of achievement attitudes and behaviors at school?

Our school district utilizes Figure 1, an ecological perspective of children's development in school, as a heuristic for exploring these types of educational questions (Thorpe, 2003). Students, with personal characteristics that influence their achievement attitudes and behaviors, find themselves growing up in various types of educational environments across their lifespan in school. The centerpiece of Figure 1 is a three dimensional block which is helpful for exploring the changing structure and function of

schools in our modern culture. One dimension of the cube emphasizes different aspects of the developing child, i.e. physical, socio-emotional, and cognitive development. The second dimension focuses upon teachers and the support they provide to children in the classroom, i.e. developmental support, academic support and relational support. The final dimension centers on the administrative aspects of schooling, i.e. resources, organization and leadership. The cube is situated in a layering of contexts similar to those presented in Bronfenbrenner's Ecological Theory of Development (Bronfenbrenner & Morris, 1998) and emphasized in Peisner-Feinberg, et al. (2001). The most immediate context outside of school for children is their home and neighborhood. Extended family and other social networks are facets of the next contextual layer that influences children's development at school. The final context acknowledges that current national ideologies, laws and customs directly influence the communities and schools in which children develop. Religious, economic and scientific changes across a nation may act to change customs and laws which guide communities and influence individual families and children at school. For instance, school researchers need to consider changes in school curriculum due to transformation in the political culture of a state or school district in examining variations in the achievement outcomes of children. Standards-based curriculum, instruction and assessment are recent developments in the culture of schooling and the timing of this educational change should be accounted for in examining the academic development of children in school.

Analyzing academic development. Analytically, hierarchical linear models (HLMs) permit researchers to consider each student as a group allowing repeated measures within each subject in the same manner as observations from different subjects

within a group. As we shall see the growth curve approach in HLMs makes it possible to study intra-individual academic development and to examine what characteristics may be associated with inter-individual differences in that development (Raudenbush, 1988; 1993).

Like any other statistical model, HLMs are not statements about sample behavior; but reflect a theoretical population process that has generated the sample data (Francis, Shaywitz, Stuebing, Shaywitz & Fletcher, 1994; Singer & Willett, 2003). The HLM models discussed in this paper represent only one of two classes of multilevel models, i.e. models that explore the interactions between individuals and the social groups or contexts to which they belong. This class contains multilevel regression models; the other class of multilevel models is for covariance structures and will not be discussed in this paper (See Reise & Duan, 2003; Moskowitz & Hershberger, 2002; Little, Schnabel & Baumert, 2000). Raudenbush (2001) provides a set of questions that can help a researcher logically decide which class of models to use in analyzing hierarchical data.

A multilevel research problem is a problem that concerns the relationships between variables measured at different hierarchical levels, e.g. pupils nested within schools, schools nested within districts. Sometimes known as contextual modeling, the individual and context are seen as distinct sources of variability and are modeled as random influences (Snijders & Bosker, 1999). The primary goal of a multilevel analysis is to determine the direct effects of individual and group level explanatory variables and to determine if the explanatory variables at the group level (school) serve as moderators of individual-level (pupil) relationships (Hox, 2002). These analyses are best accomplished by exploring relationships among small numbers of variables, using theory

to guide small changes in the models one relationship at a time (Kreft & De Leeuw, 1999).

Academic development. Though statistical modeling is most effective when guided by sound theory, it is difficult to find an adequate theory of academic development (Alexander, P. A., 2000). Alexander believes that a theory of academic development should focus upon the process of formal learning and on the products of "schooling knowledge". This theory needs to represent changes that occur in an individual over the lifespan in a formal learning environment. Methodologically, data from experimental research is cross-sectional in nature; and therefore, in order to understand academic development, Alexander notes that researchers should construct systematic, long-term longitudinal studies. Alexander also stresses that academic development should be examined during interactions of the learner with the educational environment, i.e. teachers, peers, instructional materials. However, Alexander clearly emphasizes that research on teaching and learning does not provide a cohesive picture of the systematic changes that students should undergo cognitively, motivationally, and socioculturally as they are formally educated across the lifespan. Therefore, despite the emphasis on using theory to guide multilevel analyses, a global theory of academic development is still 'under construction'. Nevertheless, sufficient theory exists in cognitive developmental psychology to help the school researcher examine research questions such as the relationship between learners and their environments in areas like vocabulary development (Huttenlocher, Haight, Bryk, & Selzer, 1991). More importantly, even though a global theory of academic development has not yet been clearly expressed, applied school researchers can still utilize HLMs to explore

relationships between student behaviors, attitudes and background characteristics, e.g. examining the predictors of students' dropping out of school (Rumberger, 1995) or changes in violent behavior in middle childhood (Aber, Brown & Jones, 2003). Our district has chosen to use Figure 1 to guide us in the development of multilevel problems until a theory of academic development is more fully articulated.

Conceptualizations of Quantitative Change

Introduction to measuring change. Problems with measuring and analyzing changes in academic achievement stem from an inaccurate conceptualization of change (Rogosa, Brandt, Zimowski, 1982; Willet, 1988; Francis, Fletcher, Stuebing, Davidson, & Thompson, 1991). This type of change is best conceptualized as a continuing process, which is influenced by cognitive, metacognitive, and affective factors (Carlson, & Wiedl, 1992). A given level of academic development is just one point in time of an on-going, dynamic interaction between an individual student and his/her educational environment. The following discussion will clarify issues surrounding the measurement and analysis of change by contrasting two basic conceptions of change (i.e. incremental vs. process views of change).

Incremental view of change. Measurement of change, from the incremental perspective, has relied upon the difference score (i.e., post-test score minus pre-test score) as an indicator of change. This type of gain score has been used extensively in the dynamic assessment literature and has come under much scrutiny since the mid-fifties (Lord, 1956; Bereiter, 1963; Linn & Slinde, 1977; Rogosa & Willett, 1985). Early conclusions about the use of this gain score to measure change have been negative. Two issues concerning: (1) the unreliability of the difference score and its inverse relationship

to the correlation between pre-test and post-test scores, and (2) the correlation between initial status and the difference score and what this means for studying correlates of change have dominated the discussion (Francis, et al., 1991).

Addressing the first of these two issues, Rogosa (1995) asserts that with only two observations, pre- and post-test scores, the difference score is a natural estimate of the amount of true change regardless of the form of the growth curve. In addition, the difference score is a good estimate of the constant rate of change in a straight-line growth curve model. For a group of individuals who have growth curves that exhibit a high pre-test, post-test correlation with equal variances at both test times, the growth curves will be parallel to each other. If all individuals are growing or changing at the same rate there are little individual differences in true change. In this instance, the difference score can be used to estimate an average rate of change across individuals, but cannot be used to detect an absence of individual differences in change. However, with a moderate correlation between pre- and post-test scores, which implies that growth curves cross each other and that individual differences in change exist, the reliability of the difference score increases. Rogosa concludes that if there are individual differences in change, the difference score will have acceptable reliability.

In addition, correlation between scores is often viewed as the extent to which the measurement instrument is assessing the same construct at both testing periods. This is a reasonable viewpoint if there are no inter-individual differences in intra-individual change. If subjects are growing at different rates then the reliability of the difference score will likely increase, and can exceed the reliabilities of the individual tests

(Zimmerman & Williams, 1982). When growth rates vary, a low correlation between pre- and post-test scores is not an adequate indicator of construct validity.

A further criticism of the difference score stems from its inverse relationship with initial status. It appears that difference scores favor persons with certain values on the pre-test. Subjects who excel on the pre-test appear to be slow learners in terms of gain scores, because they have less far to go to reach optimal performance on the task to be learned. But, if the difference score is a sound estimate of true change, it cannot be inequitable and thus favor any type of score (Rogosa, 1995). It is the correlation between true change and true initial status that is of interest to the researcher. This correlation can be negative, zero, or positive. If subjects are growing at different rates the time chosen to represent initial status may affect the magnitude and sign of this correlation (Francis, et al., 1991). The problem lies with the observed initial status and observed difference score. Due to measurement error in the pre- and post-test scores, there is a negative bias in the correlation between observed initial status and the difference score. This correlation tends to underestimate the real population correlation between true initial status and true change (Willett, 1988). If the real population correlation is small (negative, positive, or zero) then the correlation between the observed initial status and observed difference score will tend to be negative. Therefore, interpretations of this correlation will be invalid. Therefore, the difference score is a poor statistic for studying correlates of change, whether they are initial status or any other variable of interest (Cronbach and Furby, 1970).

Researchers have also used residualized change scores in place of difference scores in the analysis of change. Concerns regarding the low reliability of the difference

score and its negative correlation with initial status have inspired researcher's use of residual change scores (Rogosa, 1995). For example, Campione and Brown (1987) used residual gain scores as a dependent measure which was regressed on learning and transfer scores. Learning scores accounted for 22% of the variance in residual gain scores and an additional 17% of the variance was explained by transfer scores. Simple correlations showed that learning and transfer scores were better predictors of residual gain scores than static ability measures (i.e., estimated IQ scores- subscales from the Wechsler Preschool and Primary Scale of Intelligence, and Raven Colored Progressive Matrices scores). However, residual change scores do not always fare better than difference scores in terms of reliability and they are not very successful in studying possible correlates of change.

To briefly explain, a residual change score, in terms of true scores, is the deviation of true outcome at time 2 from the regression prediction using true time 1 data. With fallible measures, the residual change score is the residual from the observed-score time-2 on time-1 regression. The residual change score was purportedly superior in reliability to the difference score (Linn & Slinde, 1977). However, this superiority holds only if the true-scores at time 1 and 2 have a correlation near one and equal true-score and observed-score variances across time. In addition, Rogosa (1995) presents evidence that the difference score may be more reliable than the residual change score depending upon the choice of time 1 measurement. More importantly, the residual change score perspective answers the question, "How much would individual p have changed on the attribute of interest if all individuals had started out as equal?". The better question is, "How much did individual p change on the attribute of interest?". The problem in the

first question is with the term "equal"; there is no clear-cut definition of this term. It may mean equal on true initial status, observed status, or other background characteristics. According to Rogosa, the residual change score has the same difficulties as using statistical methods to equate nonequivalent groups; and therefore, attempting to statistically adjust for preexisting differences by using residual gain scores is doomed to failure.

Finally, using residual change scores to detect correlates of change (i.e., "What kind of people are gaining or changing the most") is also problematic. Rogosa (1995) provides evidence that even with large systematic differences in growth (i.e., individual differences of growth which are linked with one or more exogenous characteristics), a correlation of growth differences with an exogenous characteristic may be near zero depending upon the choice of initial measurement. Residual change correlations are founded upon an adjustment for the effects of initial status, and those effects change with the choice of time at which initial status is measured. Rogosa concludes: "The fatal flaw of the residual change procedures is the attempt to assess correlates of change by ignoring individual growth" pg.24.

Process view of change. Willett (1988) believes that measurement problems regarding change arise from a misconception of change. Instead of viewing change as incremental, which reflects learning as an amount learned (i.e., a quantifiable acquisition of skills or attitudes), change should be conceptualized as a process of continual development over time. The emphasis shifts away from the amount of change to the individual growth trajectory that reflects the process of change. The amount of true change is now conceptualized as a result of an individual's underlying growth trajectory.

This perspective of change necessitates a shift from two observations in studying change to multiple observations for studying change. Though two observations do provide information about change, this type of design has several limitations for studying individual growth trajectories. With two time points, a growth curve, specifically a straight line, can be fitted to the points. Alternative curves could also pass through the points (i.e. exponential or logistic growth curves), however, with only two points, there is insufficient information to distinguish between the curves and there is no information about the adequacy of the chosen curve in depicting change. In addition, there is not enough information to use in the estimation of the parameters of the curves. Finally, errors in measurement require more than two observations to precisely describe the growth curve (Rogosa, 1995).

The only information that can be obtained with two measurement points is the amount of change, and there are problems in obtaining this value. For growth curves that are not straight-line curves, different measurement times may produce various estimates of the amount of change. Therefore, in a study with only two observations of change, the time points used for measuring change need to be carefully chosen. Observations over different time periods could yield contradictory information regarding individual differences in change (Rogosa, 1995).

In conclusion, two observations can be used to estimate an average rate of change, but not individual growth curves which model individual differences in growth and correlates of growth (Rogosa and Willett, 1985). Researchers have analyzed change as a characteristic of groups, rather than change as a characteristic of individuals due to the afore-mentioned problems in measuring change. Assessment procedures should be used

to understand inter-individual differences in intra-individual change and correlates of change. But these assessment procedures need to: (1) replace pre-test, post-test designs with multiple test designs and (2) model individual growth curve trajectories with their correlates. This will enable assessment researchers to study, not only the amount of change, but the nature of individual change. Ideally, growth models need to be developed so that the individual growth parameters are interpretable in terms of the learning process being modeled (Willett, 1989).

Methods for Analyzing Longitudinal Data

Traditional methods for analyzing multi-wave data. Researchers interested in studying change, e.g. dynamic assessment researchers, tend to study mean group differences in change over time. For example, Burns, Delclos, Vye and Sloan (1992), in a study on cognitive strategies, examined two types of dynamic assessment procedures, hinting and mediation, and compared these results with each other and static assessment. Two groups of students, mentally handicapped and normally-developing were assessed. A repeated-measures analysis of variance (pre-test and post-test by handicap group by assessment group ANOVA) found that handicapped children had significant increases in performance after receiving mediation, but not after receiving hints. Normally developing children had significant increases after each type of assessment. In another study, Day and Zajakowski (1991) used a multivariate approach to a mixed factor model (MANOVA). They compared assisted and unassisted performance on a reading comprehension task of average readers with children who had learning disabilities. The 2(Group: average, poor readers) X 2(Test Time: pre-test, post-test) X 3 (Topic Sentence Placement: First, Last or Missing) multivariate analyses of variance found two significant

effects (i.e., Test Time and Topic Sentence Placement). Students did better on the post-test than the pre-test and scores on the topic-sentence-first paragraph was significantly higher than the topic-sentence-last paragraph. These two studies exemplify the traditional approach for studying mean group differences in change over time. However, use of group means may mask individual changes that occur in opposite directions and hence cancel each other out. Marked changes may take place at the individual level in spite of almost constant average levels in an attribute across time. Many development researchers believe that the most essential issue in developmental psychology is the individual's own growth trajectory. Baltes, Reese, and Nesselroade (1977) emphasized early on that the study of inter-individual differences in intra-individual change is fundamental to understanding human development, but statistical methods necessary for analysis of such change were not available at that time.

The emphasis on mean change in ANOVA and MANOVA analyses are also misleading because they incorrectly suggest that two waves of data are adequate to study change. They also require that all individuals be measured at the same time points. As we have seen, multi-wave data are needed to adequately understand individual growth curves. In addition, measuring all subjects at identical time points is problematic in many developmental research studies due to unavailability of subjects because of illness or scheduling problems.

ANOVA and MANOVA analyses can easily be extended to study multi-wave datasets. But this is still consistent with the incremental view of change since it uses a time-ordered sequence of difference scores between adjacent time waves (Francis, et al., 1991). Group differences in change are found in the Group Factor x Time interaction.

Trend analysis can also be used to study change as an alternative approach to ANOVA and MANOVA analyses. Means can be tested to see if they increase or decrease linearly across time. Effects of subject variables on rates and patterns of change can also be examined. The MANOVA approach to repeated measures including trend analyses provides the best test for group differences due to relatively nonrestrictive assumptions required for tests of significance. However, this is still a limited approach, since it requires that all subjects have data at the same time points. In addition, the spacing of the time points must be identical for all subjects. Finally, ANOVA and MANOVA analyses require discrete predictors of growth; continuous measures of growth cannot be used. Most importantly, these methods view within-group individual differences in intra-individual change as error. These methods, therefore, obscure interesting and important information regarding individual growth if these individual differences can be explained by continuous characteristics of individuals.

In conclusion, traditional ways of analyzing change emphasize group change over individual change. They also have stringent requirements. All subjects must have data at all the same time points and these time points must be equally spaced. In addition, variability in change among individuals is treated as error, and not as something of value to be studied. Finally, by functioning under the incremental view of change, educational researchers miss out on the opportunity to study inter-individual differences in intra-individual change and the covariates of change. Researchers might consider switching from using an incremental perspective of change to a process view of change.

Hierarchical linear modeling. Willett (1988), Bryk and Raudenbush (1987, 1992) and Raudenbush and Bryk (2002) have applied hierarchical linear models in education

settings. They begin by formulating a model for change at an individual level. This focuses the study of change on inter-individual differences in intra-individual change. Each subject is considered to be a "group" of observations. The repeated measure within each subject is treated as observations from different subjects within a group. Therefore, the researcher can consider time or age to be one variable and a behavioral or personality dimension as another variable within subjects. The dimension of interest is then regressed on time/age and regression equations computed for each subject. The intercept and slope parameters in these regression equations are treated as new variables that are added to each subject's data. The second step in the analyses then treats these variables as outcome variables in a new series of analyses designed to determine what other variable may be associated with inter-individual differences in intra-individual change.

This next section will provide a brief summary of the benefits of individual growth curves for modeling longitudinal datasets from the Francis, et al., 1991 study. A subject's score reflects an ongoing process which underlies continuous change in a characteristic (e.g., behaviors or cognitive skills). This change is characterized by a set of parameters which govern a continuous curve. These parameters are then used to describe the relationship between the characteristic of interest and time. A linear increase in performance can be modeled as the slope of the line which related the characteristic to time. The model can be written as: $Y_{it} = \pi_{0i} + \pi_{1i}a_{it} + R_{it}$. This is a description of a straight line which is dependent upon time (t) and specific to an individual (i). The first parameter π_{0i} is the intercept, which describes the average level of Y for subject i when a is 0. The second parameter, π_{1i} , describes the average rate of change in Y for subject i. Usually, a_{it} , is the age of subject i at time t. But it can also be a different time-related

marker (i.e., number of follow-up sessions). R_{it} is random error in Y for subject i at time t . It is an indication of the extent to which Y_{it} does not all fall on the curve for subject i .

This example of a mathematical model for individual change, though similar to the mathematical model used in trend analysis, has the subscript i attached to the variables and parameters. This indicates that this mathematical model is for individual subjects and not a mathematical model of means. Of more importance is the variability of the growth parameter, π_{1i} , among individuals. If this parameter or any other growth parameter (i.e., quadratic growth parameter) varies across subjects, then it is possible to identify correlates of change by answering these questions, "Are the parameter values constant across subjects?" and "Do variations in the parameters systematically relate to characteristics of individuals?" These questions generate a second mathematical model where the two parameters, π_{0i} and π_{1i} , are dependent variables. Subject characteristics, which are viewed as correlates of change such as initial status on Y , can be used as independent variables. These correlates of change can be analyzed with a second mathematical model: $\pi_{1i} = \beta_{10} + \beta_{11}X_{11i} + \dots + \beta_{1p-1}X_{1p-1i} + U_{1i}$. In this model there are $p-1$ covariates of change being modeled. The β 's reflect the effects of the p th covariate on the rate of change in Y . U_{1i} is random error and indicates the extent to which the variability in the rate of change is not explained by the covariates.

These two mathematical models emphasize important components of the process view of change. The first model depicts individual growth, while the second model is used to explain the correlates of growth. With more than two waves of data, the reliability of growth parameters can be estimated. In addition, these estimates can be used to disattenuate estimated correlations between true change and covariates of change.

Furthermore, subjects with incomplete datasets can still be used in the analyses. A differential weighting of the data can be used to give subjects whose parameters have been estimated with more precision more influence in the analysis. This is essential in studying the correlates of change. Finally, multi-wave data provides a more accurate depiction of the true growth curve. It is clear, from the above discussion, that there are conceptual and statistical advantages to using individual growth methods in studying longitudinal data.

Selection of an appropriate academic growth curve model. Nesselroade (1991) provides an insightful chapter on inter-individual differences in intra-individual change. He emphasizes that a countless universe of persons, variables, and occasions exist for the study of change or for our purposes academic growth. Nesselroade notes that a researcher should distinguish between growth that characterizes most people and growth that characterizes individuals. Therefore, those who study academic growth need to simultaneously consider research design, measurement and analysis; and, in addition, they should study of growth at the junction of variation across persons, variables and occasions. Furthermore, it is the selection of occasions that is fundamental to the study of growth. For example, if the sampling of occasions is too narrow the research may pick up a "cause" or an "effect" but not both, thereby limiting the researcher's capacity to establish a cause-effect relationship. Additionally, researchers postulate different types of growth curves dependent upon the characteristic being examined. A straight line, logistic curves, cubic polynomials, etc. may represent hypothesized growth curves.

Burchinal and Appelbaum (1991) discuss different quantitative growth curve models in their paper on estimating individual developmental functions. The main focus

on their paper is on the selection of appropriate growth curve models. Burchinal, Bailey and Snyder (1994) underscore the need to use individual growth curve modeling if the underlying growth process differs in a meaningful way across individuals. From their perspective, developmental processes can be described by a developmental function if: (1) time-related change is present, (2) researcher's assumptions regarding the growth process are appropriate, and (3) the data collected is the actual and not relative amount of the characteristic possessed by a given individual at a given time. They emphasize that longitudinal data are also necessary because repeated observations of the same individuals over time allow the examination of intraindividual change that is not confounded by interindividual differences. Burchinal and Appelbaum also underscore the need to use individual growth curve modeling if the underlying growth process differs in a meaningful way across individuals. The growth function should then be estimated for each individual; individual differences deemed to be trivial dictate a population growth curve model (See Pollitt, Huang & Jahari, 2000). For instance, Burchinal, Lee & Ramey (1989) used individual cubic polynomial growth curves to describe intraindividual differences in preschooler's intellectual development. They also identified prototypic intellectual growth curves and grouped children according to these curves. The groups of children generated by the prototypic growth curves differed by parental attitudes and practices.

Finally, Burchinal and Appelbaum stress that growth tends to be complicated; therefore, a linear function may not be an appropriate model for academic growth. This is due to the rate of change over time during a growth spurt being variable and not constant, i.e. the rate of growth may be fast at the beginning of academic growth and then

taper off as growth comes to an end. Thus, it is important to choose an appropriate model of growth according to established theory or empirical findings.

Conclusion. Problems with measuring and analyzing change in academic achievement are derived from an inaccurate conceptualization of change. Furthermore, research on academic development, or on student progress in school, is challenging, since an examination of student growth involves nested structures of repeated observations within individuals who in turn are nested within school settings. This paper, as Part I in a three-part series on modeling academic development, has shown that hierarchical linear models can consider each student as a group, allowing repeated measures within each subject. More importantly, a growth curve approach in hierarchical linear models makes it possible to study intra-individual change, and to examine which characteristics may be associated with inter-individual differences in intra-individual change.

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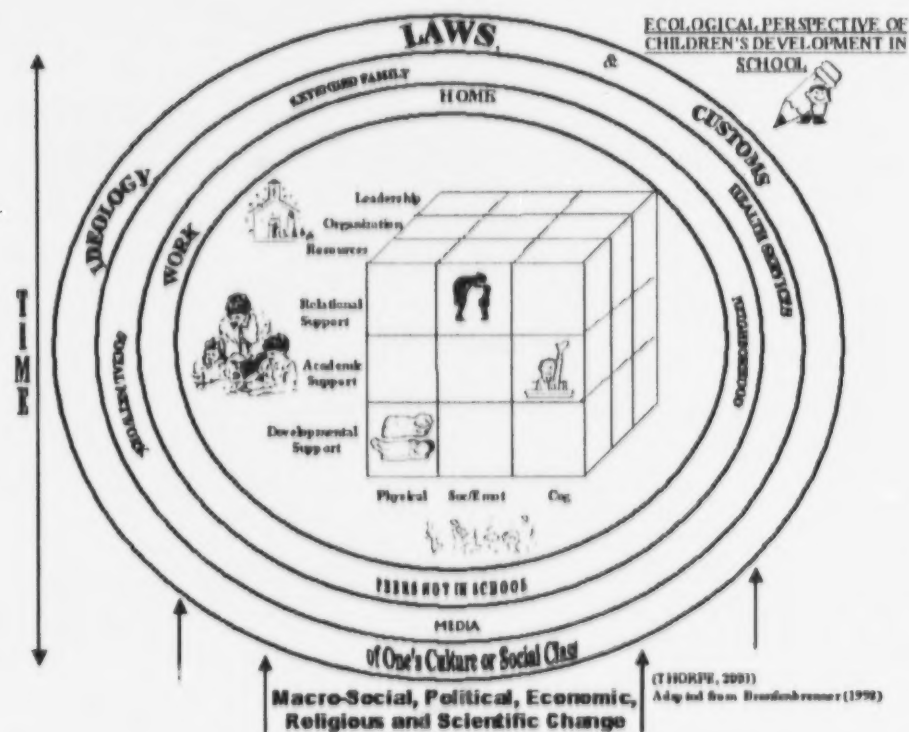
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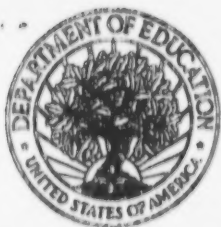
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Figure 1. Ecological perspective of children's development in school.



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